UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

HYDRAULIC MODEL STUDIES OF THE INLET TRANSITION AT RADAR PUMPING PLANT, COLUMBIA BASIN PROJECT, WASHINGTON

Report No. Hyd-547

Hydraulics Branch
DIVISION OF RESEARCH

OFFICE OF CHIEF ENGINEER
DENVER, COLORADO

April 7, 1965

CONTENTS

ABSTRACT

Limited model tests were performed to compare the hydraulic characteristics of an angled transition with the characteristics of a symmetrical transition, and to determine the configuration of appurtenances required to improve the flow distribution in the angled transition. The appearance of flow patterns in the transitions indicated that the symmetrical transition was better than the angled transition. The angled transition was made to operate satisfactorily by the addition of curved guide walls near the upstream end of the transition. The symmetrical transition was recommended for installation. No attempt was made to measure head loss or velocity distribution in the transitions.

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DESCRIPTORS--*canals/ *pumping plants// *transitions/ structures// *hydraulic models/ canal design/ eddies/ research and development/ flow control/ symmetry/ model tests/ laboratory tests/ hydraulics/ velocity distribution/ shapes/ *inlets/ flumes/ sedimentation/ dyes

IDENTIFIERS--Radar Pumping Plant/ Columbia Basin Project/ Washington/ flow patterns/ symmetrical transitions/ angled transitions/ hydraulic characteristics/ guide walls/

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PURPOSE

The study was conducted to compare the hydraulic characteristics of an angled transition with the characteristics of a symmetrical transition, and to determine the configuration of appurtenances required to improve the flow distribution in the angled transition.

CONCLUSIONS

1. Surface flow patterns indicated that the flow at the pump intake was better distributed with the symmetrical transition than with the angled transition. Flow patterns in the angled transition were improved by the addition of curved guide walls near the upstream end of the transition.

2. The symmetrical transition was recommended for use in the prototype structure.

ACKNOWLEDGMENT

The study described in this report was accomplished through cooperation between the Canals Branch, Division of Design, and the Hydraulics Branch, Division of Research. Photography was by W. M. Batts, Office Services Branch.

INTRODUCTION

Radar Pumping Plant is a feature of the Wahluke Branch Canal system, Columbia Basin Project, Washington. The plant is located in southern Washington near Othello, Figure 1. The subject transition connects a 15-foot-wide rectangular bench flume to the 9-unit pumping plant (Units 1 and 2 were located in a single bay), Figure 2. (Figure 2 shows the preliminary angled transition.) The model test discharge simulated a prototype discharge of 426 cubic feet per second at a flow-depth of 6.9 feet in the flume. The particular conditions of pumping plant location and bench flume alinement which resulted in an asymmetrical configuration of the transition were determined by foundation conditions and other factors. Although a more direct approach to the plant would have been desirable, the hill side on the left bank (see Figure 2) made this plan economically impractical.

Other model studies1/ have shown that an angled transition can result in nonuniform velocity distribution in the transition with large areas of reverse current. Such nonuniformity results in increased head loss and unequal distribution of flow to the pump intakes, with accompanying reduction in pump efficiency. Also, the eddy currents allow deposition of sediment and trapping of surface debris. However, in the cited study, 1/ these conditions were not severe and an angled transition was selected because of economic considerations.

THE MODEL

The 1:18 scale model originally included approximately a 120-foot length of the bench flume, the angled transition of Figure 2, and the eight pump intake bays. The model was later modified to include a symmetrical transition with a short curved approach flume.

The transition and bench flume were fabricated from wood and the pump intakes were simulated by sheet metal slide gates. As the study was of a limited general nature, the downstream end of the model transition did not identically simulate the prototype transition. The floor was horizontal as compared with a sloping prototype floor. Dividing piers were installed to simulate flow conditions at the entrances to the pump intake sumps, and the pump sumps were not modeled. These discrepancies between model and prototype configurations are insignificant and should have little effect on the conclusions drawn from the model tests.

Water was supplied to the model through a recirculating system and the flow rate was measured by a volumetrically calibrated venturi meter.

THE INVESTIGATION

Only limited tests were made on the transition to the Radar Pumping Plant. The performance of the transition designs and the effects

1/ "Hydraulic Model Studies of the Canal Transition at the Forebay Pumping Plant, San Luis Unit, Central Valley Project, California," by D. L. King. Hydraulics Branch Report No. Hyd-542, 1965."

of appurtenances were evaluated on the basis of the appearance of the water surface flow patterns and the movement of dye streams on the transition floor. No attempt was made to measure head loss or velocity distribution in the small model.

The Angled Transition, Preliminary Design

The original design of the transition consisted of a straight approach flume alinement and an angled transition as shown in Figure 2. The left wall diverged approximately 85° and the right wall diverged about 5°. The transition width changed from 15 to 126.5 feet in a length of approximately 90 feet.

The model demonstrated a strong rotational circulation in the transition, Figure 3A. The high velocity flow in front of Units 2 through 5 (as demonstrated by the length of the flow lines) caused small vortices to trail off the dividing piers. Bay 8 showed a strong rotation within the intake bay, Figure 3A.

Curved guide walls were placed in the upstream portion of the transition to provide better flow distribution. The guide walls broke up the strong rotational circulation into smaller, slow-moving eddies, Figure 3B, and flow distribution to the intakes was more uniform.

The configuration of the recommended guide walls, developed through a series of trials, is shown in Figure 4. The left wall was 3 feet 9 inches high; the right wall was 4 feet 6 inches high. The simulated thickness of both walls was approximately 8 inches. During operation at design depth, both walls were beneath the water surface.

The Symmetrical Transition, Recommended Design

The angled transition was replaced by a symmetrical transition with a short curved approach flume, Figure 5. The alinement of the straight portion of the flume upstream from Station 1+56.51, the P.C. of the curve, remained the same as shown in Figure 2. The model included the curve and approximately 90 feet of straight flume upstream from the curve.

Flow conditions in the symmetrical transition were very good. Two large, slow-moving eddies moved counterclockwise on the left side of the transition and clockwise on the right side, Figure 6. The eddy on the left side was larger, due to the influence of the curved approach channel upstream of the expanding section. Flow distribution at the pump sump intakes was fairly uniform.

Generally, the flow appearance and distribution in the symmetrical transition were better than those observed during operation of the modified angled transition (with guide walls); therefore, the symmetrical transition was recommended for use in the prototype structure.

FIGURE 1
REPORT HYD-547

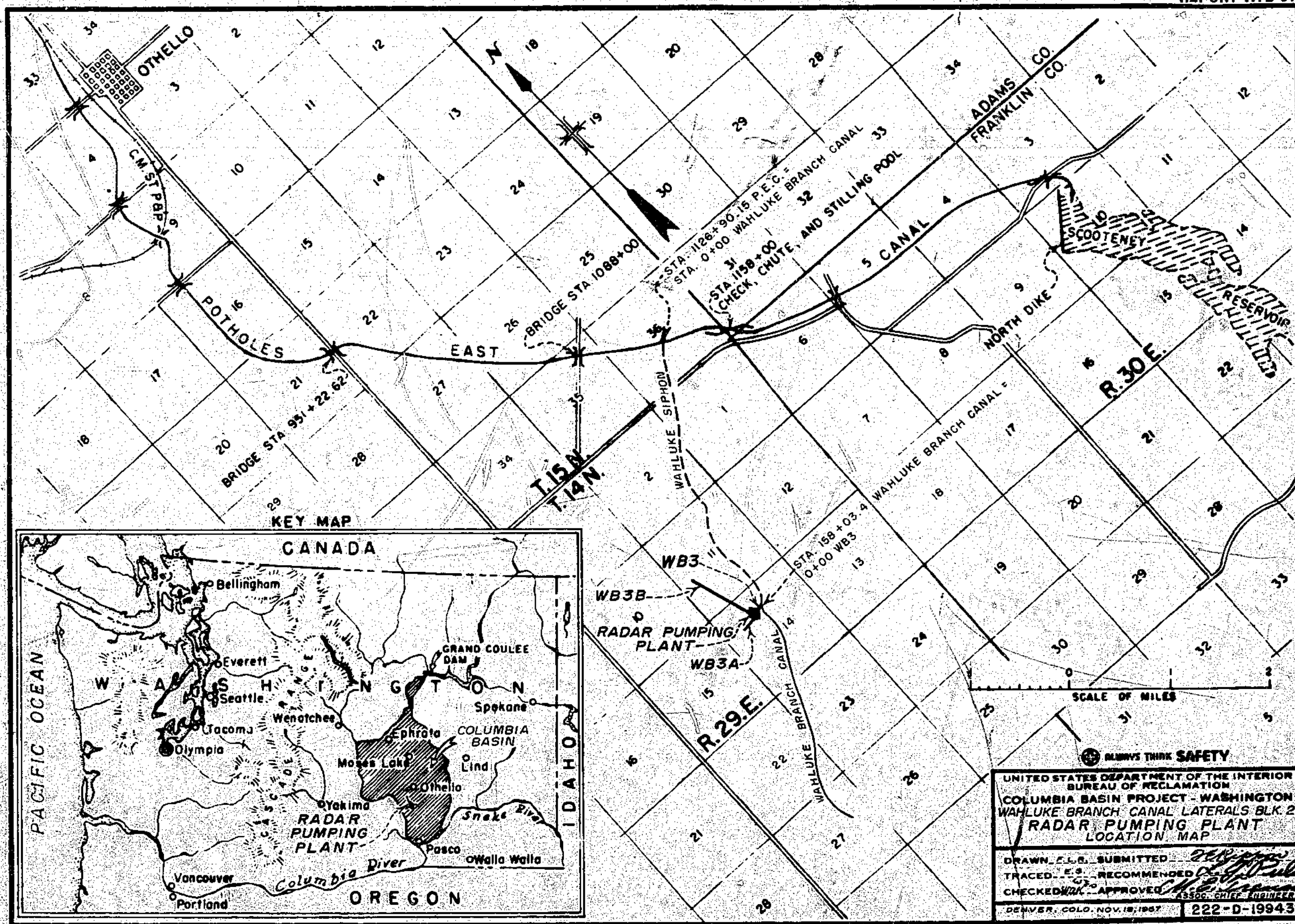
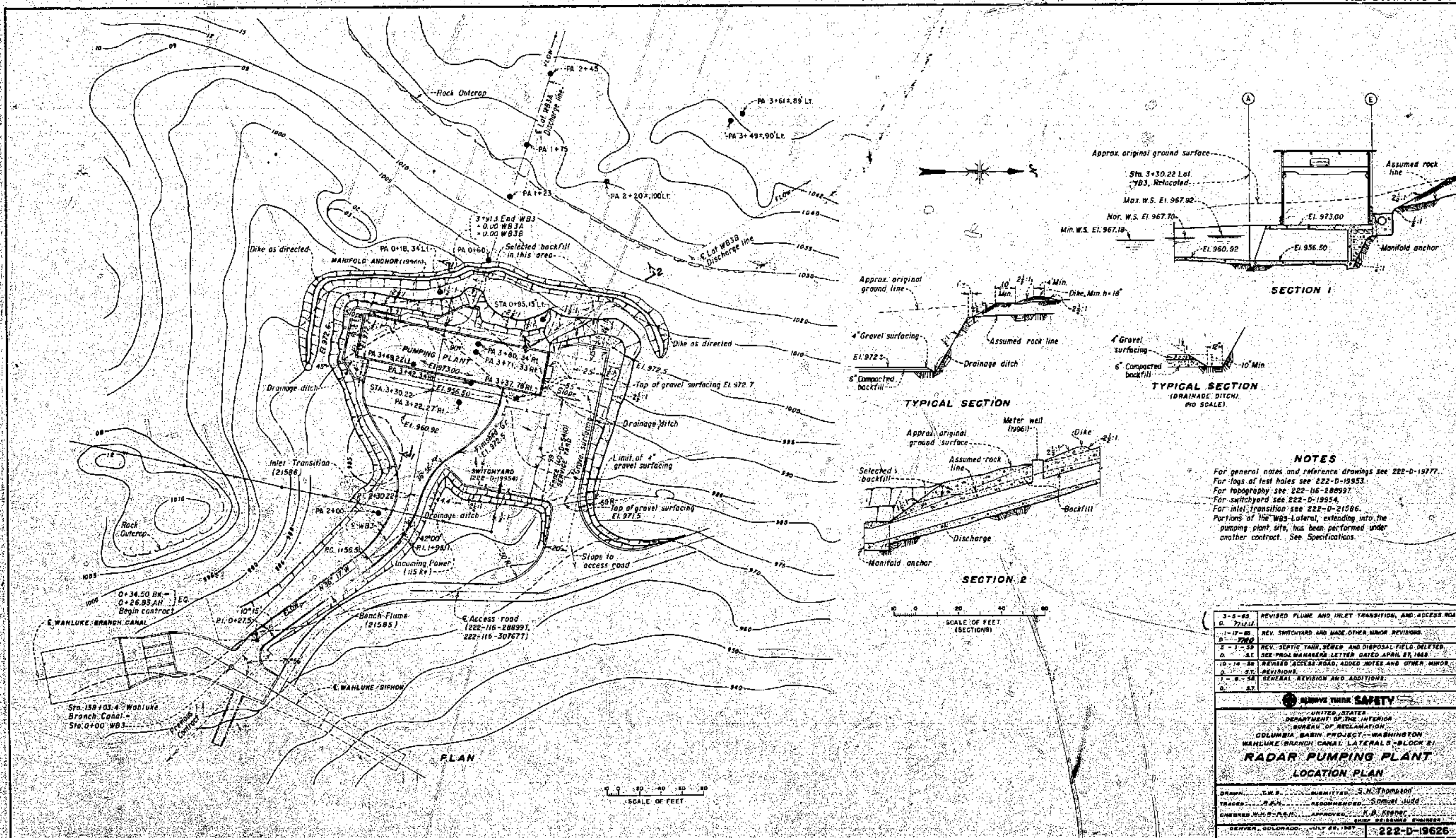
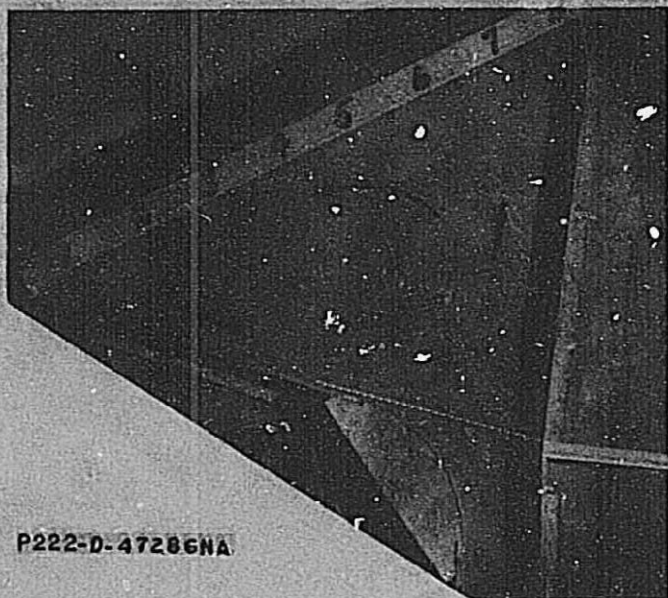
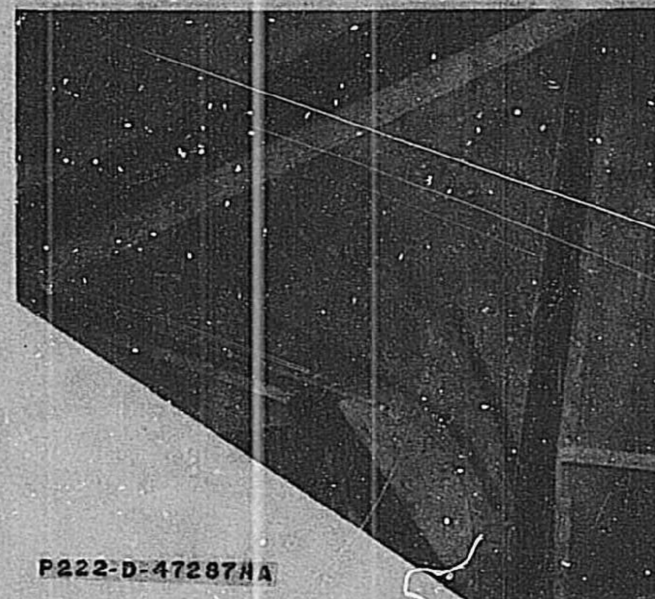


FIGURE 2
REPORT HYD-547





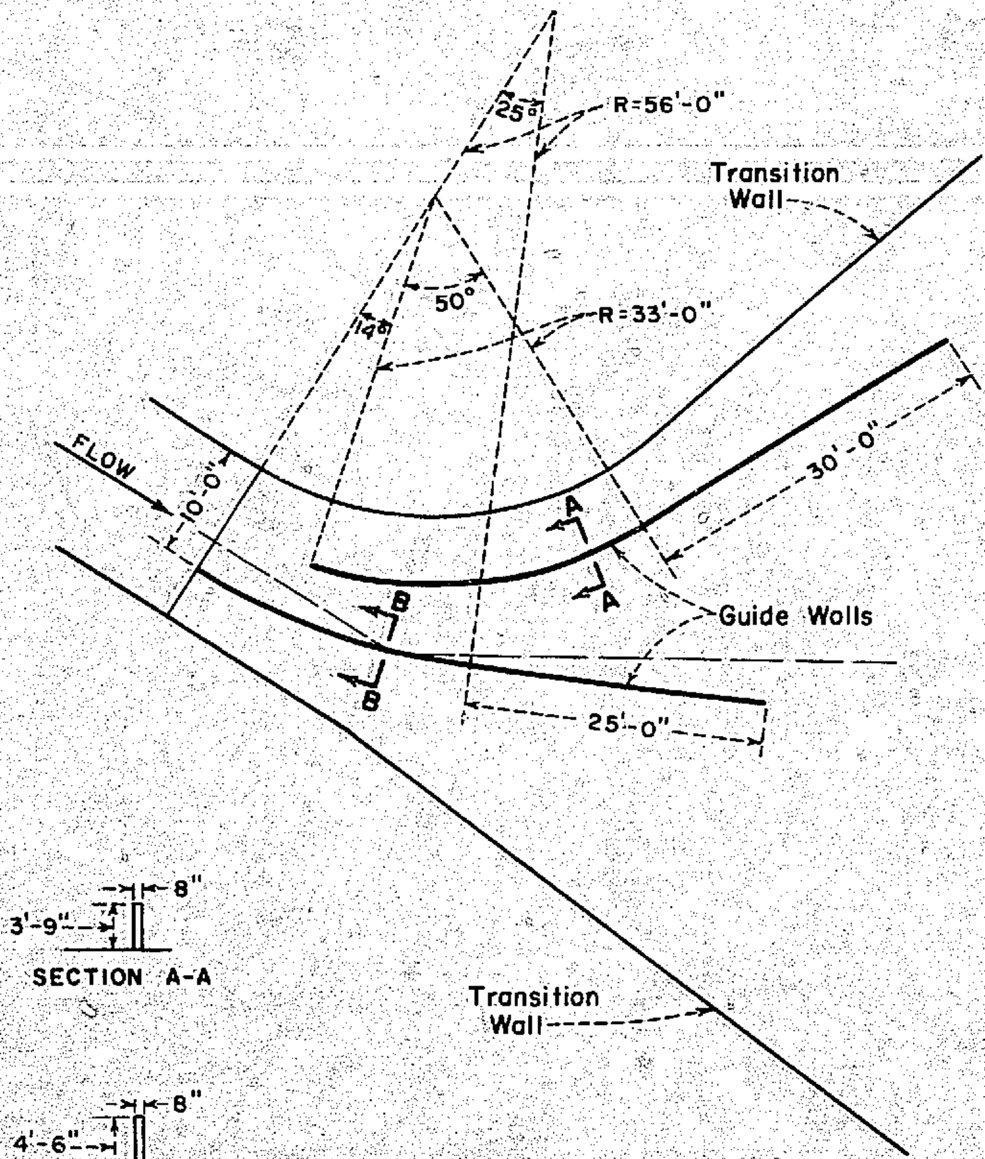
A. Angled transition, preliminary design.



B. Angled transition with curved guide walls.

RADAR PUMPING PLANT
INLET TRANSITION
1:18 Scale Model

Surface Flow Patterns in the
Angled Transition
Q = 426 cfs, flow depth = 6.9 feet

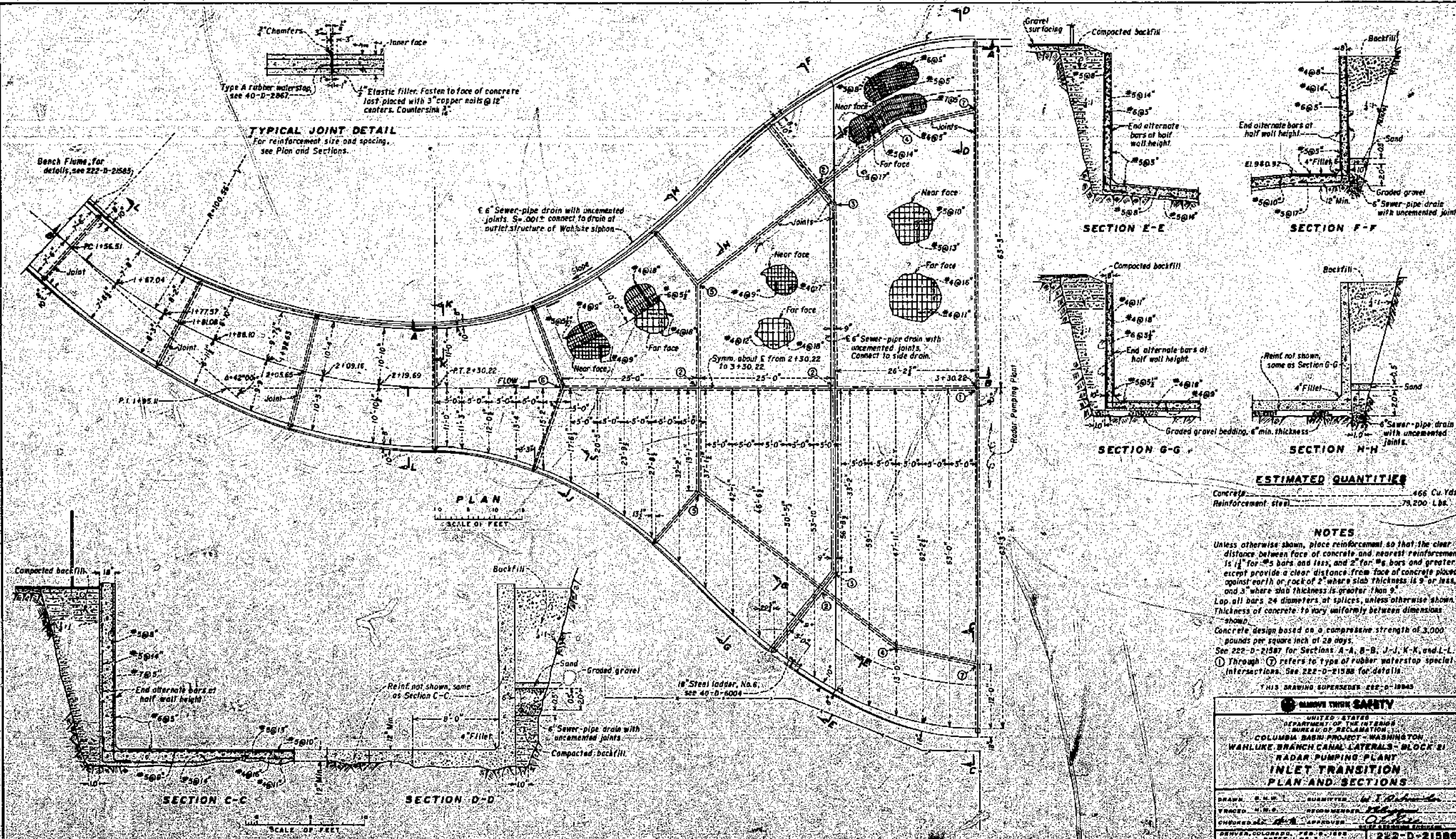


RADAR PUMPING PLANT
INLET TRANSITION

1:18 SCALE MODEL

CONFIGURATION OF RECOMMENDED GUIDE
WALLS FOR ANGLED TRANSITION

FIGURE 5
REPORT HYD-547



ESTIMATED QUANTITIES

Concrete .... 466 Cu. Yds.
Reinforcement steel .... 79,200 Lbs.

NOTES

Unless otherwise shown, place reinforcement so that the clear distance between face of concrete and nearest reinforcement is 1½" for #5 bars and less, and 2" for #6 bars and greater; except provide a clear distance from face of concrete placed against earth or rock of 2" where slab thickness is 9" or less, and 3" where slab thickness is greater than 9".

Lap all bars 24 diameters at splices, unless otherwise shown.

Thickness of concrete to vary uniformly between dimensions shown.

Concrete design based on a compressive strength of 3,000 pounds per square inch at 28 days.

See 222-D-21587 for Sections A-A, B-B, J-J, K-K, and L-L.

1 Through 7 refers to type of rubber waterstop special intersections. See 222-D-21588 for details.

THIS DRAWING SUPERSEDES 222-D-18845

ALWAYS THINK SAFETY

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLUMBIA BASIN PROJECT - WASHINGTON
WAHLUKE BRANCH CANAL LATERALS - BLOCK 21
RADAR PUMPING PLANT
INLET TRANSITION
PLAN AND SECTIONS

DRAWN ... SUBMITTED ...
TRACED ... RECOMMENDED ...
CHECKED ... APPROVED ...

DENVER, COLORADO ...
222-D-21586

Figure 6
Report Hyd-547

Q = 426 cfs, flow depth = 6. 9 feet

RADAR PUMPING PLANT
INLET TRANSITION
1:18 Scale Model

Surface Flow Patterns in the
Symmetrical Transition

7-1750
(10-64)

CONVERSION FACTORS--BRITISH TO METRIC UNITS OF MEASUREMENT

The following conversion factors adopted by the Bureau of Reclamation are those published by the American Society for Testing and Materials (ASTM Metric Practice Guide, January 1964) except that additional factors (*) commonly used in the Bureau have been added. Further discussion of definitions of quantities and units is given on pages 10-11 of the ASTM Metric Practice Guide.

The metric units and conversion factors adopted by the ASTM are based on the "International System of Units" (designated SI for Systeme International d'Unites), fixed by the International Committee for Weights and Measures; this system is also known as the Giorgi or MKSA (meter-kilogram (mass)-second-ampere) system. This system has been adopted by the International Organization for Standardization in ISO Recommendation R-31.

The metric technical unit of force is the kilogram-force; this is the force which, when applied to a body having a mass of 1 kg, gives it an acceleration of 9.80665 m/sec/sec, the standard acceleration of free fall toward the earth's center for sea level at 45 deg latitude. The metric unit of force in SI units is the newton (N), which is defined as that force which, when applied to a body having a mass of 1 kg, gives it an acceleration of 1 m/sec/sec. These units must be distinguished from the (inconstant) local weight of a body having a mass of 1 kg; that is, the weight of a body is that force with which a body is attracted to the earth and is equal to the mass of a body multiplied by the acceleration due to gravity. However, because it is general practice to use "pound" rather than the technically correct term "pound-force," the term "kilogram" (or derived mass unit) has been used in this guide instead of "kilogram-force" in expressing the conversion factors for forces. The newton unit of force will find increasing use, and is essential in SI units.

Table 1

QUANTITIES AND UNITS OF SPACE

Multiply	By	To obtain
	LENGTH	
Mil	25.4 (exactly)	Micron
Inches	25.4 (exactly)	Millimeters
	2.54 (exactly)*	Centimeters
Feet	30.48 (exactly)	Centimeters
	0.3048 (exactly)*	Meters
	0.0003048 (exactly)*	Kilometers
Yards	0.9144 (exactly)	Meters
Miles (statute)	1,609.344 (exactly)*	Meters
	1.609344 (exactly)	Kilometers
	AREA	
Square inches	6.4516 (exactly)	Square centimeters
Square feet	929.03 (exactly)*	Square centimeters
	0.092903 (exactly)	Square meters
Square yards	0.836127	Square meters
Acres	0.40469*	Hectares
	4,046.9*	Square meters
	0.0040469*	Square kilometers
Square miles	2.58999	Square kilometers
	VOLUME	
Cubic inches	16.3871	Cubic centimeters
Cubic feet	0.0283168	Cubic meters
Cubic yards	0.764555	Cubic meters
	CAPACITY	
Fluid ounces (U.S.)	29.5737	Cubic centimeters
	29.5729	Milliliters
Liquid pints (U.S.)	0.473179	Cubic decimeters
	0.473166	Liters
Quarts (U.S.)	9,463.58	Cubic centimeters
	0.946358	Liters
Gallons (U.S.)	3,785.43*	Cubic centimeters
	3.78543	Cubic decimeters
	3.78533	Liters
	0.00378543*	Cubic meters
Gallons (U.K.)	4.54609	Cubic decimeters
	4.54596	Liters
Cubic feet	28.3160	Liters
Cubic yards	764.55*	Liters
Acre-feet	1,233.5*	Cubic meters
	1,233,500*	Liters

Table II

QUANTITIES AND UNITS OF MECHANICS

Multiply	By	To obtain
MASS		
Grains (1/7,000 lb)	64.79891 (exactly)	Milligrams
Troy ounces (480 grains)	31.1035	Grams
Ounces (avdp)	28.3495	Grams
Pounds (avdp)	0.45359237 (exactly)	Kilograms
Short tons (2,000 lb)	907.185	Kilograms
	0.907185	Metric tons
Long tons (2,240 lb)	1,016.05	Kilograms
FORCE/AREA		
Pounds per square inch	0.070307	Kilograms per square centimeter
	0.689476	Newtons per square centimeter
Pounds per square foot	4.88243	Kilograms per square meter
	47.8803	Newtons per square meter
MASS/VOLUME (DENSITY)		
Ounces per cubic inch	1.72999	Grams per cubic centimeter
Pounds per cubic foot	16.0185	Kilograms per cubic meter
	0.0160185	Grams per cubic centimeter
Tons (long) per cubic yard	1.32894	Grams per cubic centimeter
MASS/CAPACITY		
Ounces per gallon (U.S.)	7.4893	Grams per liter
Ounces per gallon (U.K.)	6.2362	Grams per liter
Pounds per gallon (U.S.)	119.829	Grams per liter
Pounds per gallon (U.K.)	99.779	Grams per liter
BENDING MOMENT OR TORQUE		
Inch-pounds	0.011521	Meter-kilograms
	1.12985×10^{6}	Centimeter-dynes
Foot-pounds	0.138255	Meter-kilograms
	1.35582×10^{7}	Centimeter-dynes
Foot-pounds per inch	5.4431	Centimeter-kilograms per centimeter
Ounce-inches	72.008	Gram-centimeters
VELOCITY		
Feet per second	30.48 (exactly)	Centimeters per second
	0.3048 (exactly)*	Meters per second
Feet per year	0.965873×10^{-6}*	Centimeters per second
Miles per hour	1.609344 (exactly)	Kilometers per hour
	0.44704 (exactly)	Meters per second
ACCELERATION*		
Feet per second^2	0.3048*	Meters per second^2
FLOW		
Cubic feet per second (second-feet)	0.028317*	Cubic meters per second
Cubic feet per minute	0.4719	Liters per second
Gallons (U.S.) per minute	0.06309	Liters per second
FORCE*		
Pounds	0.453592*	Kilograms
	4.4482*	Newtons
	4.4482×10^{-5}*	Dynes
WORK AND ENERGY*		
British thermal units (Btu)	0.252*	Kilogram calories
	1,055.06	Joules
Btu per pound	2.326 (exactly)	Joules per gram
Foot-pounds	1.35582*	Joules
POWER		
Horsepower	745.700	Watts
Btu per hour	0.293071	Watts
Foot-pounds per second	1.35582	Watts
HEAT TRANSFER		
Btu in./hr ft^2 deg F (k, thermal conductivity)	1.442	Milliwatts/cm deg C
	0.1240	Kg cal/hr m deg C
Btu ft/hr ft^2 deg F	1.4880*	Kg cal m/hr m^2 deg C
Btu/hr ft^2 deg F (C, thermal conductance)	0.568	Milliwatts/cm^2 deg C
	4.882	Kg cal/hr m^2 deg C
Deg F hr ft^2/Btu (R, thermal resistance)	1.761	Deg C cm^2/milliwatt
Btu/lb deg F (c, heat capacity)	4.1868	J/g deg C
Btu/lb deg F	1.000*	Cal/gram deg C
Ft^2/hr (thermal diffusivity)	0.2581	Cm^2/sec
	0.09290*	M^2/hr
WATER VAPOR TRANSMISSION		
Grains/hr ft^2 (water vapor transmission)	16.7	Grams/24 hr m^2
Perms (permeance)	0.659	Metric perms
Perm-inches (permeability)	1.67	Metric perm-centimeters

Table III

OTHER QUANTITIES AND UNITS

Multiply	By	To obtain
Cubic feet per square foot per day (seepage)	304.8*	Liters per square meter per day
Pound-seconds per square foot (viscosity)	4.8824*	Kilogram second per square meter
Square feet per second (viscosity)	0.02903* (exactly)	Square meters per second
Fahrenheit degrees (change)*	5/9 exactly	Celsius or Kelvin degrees (change)*
Volts per mil	0.03937	Kilovolts per millimeter
Lumens per square foot (foot-candles)	10.764	Lumens per square meter
Ohm-circular mils per foot	0.001662	Ohm-square millimeters per meter
Millicuries per cubic foot	35.3147*	Millicuries per cubic meter
Milliamps per square foot	10.7639*	Milliamps per square meter
Gallons per square yard	4.527219*	Liters per square meter
Pounds per inch	0.17858*	Kilograms per centimeter

ABSTRACT

Limited model tests were performed to compare the hydraulic characteristics of an angled transition with the characteristics of a symmetrical transition, and to determine the configuration of appurtenances required to improve the flow distribution in the angled transition. The appearance of flow patterns in the transitions indicated that the symmetrical transition was better than the angled transition. The angled transition was made to operate satisfactorily by the addition of curved guide walls near the upstream end of the transition. The symmetrical transition was recommended for installation. No attempt was made to measure head loss or velocity distribution in the transitions.

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